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Improving Surface Hardness of the Aluminum Plate by Adding Alumina Powder by Friction Stir Process

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Abstract : Research is carried out on the effect of introducing Alumina particles Al_2O_3, which has increased the mechanical properties of 6063 Aluminium alloy. This can be achieved by incorporating the ceramic particles on the surface of the metals/alloys via FSP technique. During the process, Alumina particles are dispersed in the surface of AA 6063 Al alloy. After dispersion, it was evaluated from the micro hardness results that the strength of the surface composite that underwent the friction stir process displayed a value that was about 1.7 times higher when compared to the areas that were unprocessed. A fairly uniform distribution of reinforcements in the respective matrix is noticed. The improvements made on mechanical properties of AA 6063 alloy combined with Al_2O_3 can be widely used in aircraft applications.
Keywords: Surface Hardness of the Aluminum Plate, Alumina Powder,Friction Stir Process.

1. Introduction

Aluminum alloys plays a vital role in engineering field as it possesses high specific strength and density. Aeronautical and automobile industries, where the usage of light weight materials is necessary, predominantly use the 6xxx group alloys[1–3]. The main alloying elements of the 6xxx series are Silicon and Magnesium. The primary α-Al matrix contains a part of these alloying elements and these elements are also partly present in the form of intermetallic phases. During the process of solidification, the formation of several intermetallic phases takes place. This formation is based on alloy composition and solidification condition. The various properties of the 6xxx alloys include relative volume fraction, morphology and chemical composition of structural constituents[4-12]. The betterment of mechanical properties was researched previously which has concentrated on heat treatment, precipitation, and age hardening[7–13]. Chemical composition and properties of AA6063 are shown in table 1.1 & 1.2.

Table 1.1 Chemical properties of AA6063

Element	Al	Si	Mg
Weight	98.8	0.40	0.70

Table 1.2 Properties of AA6063

Density (×1000 kg/m^3)	Poisson's Ratio	Elastic Modulus (GPa)	Tensile Strength (Mpa)	Yield Strength (Mpa)	Hardness (HB500)	Shear Strength (MPa)	Fatigue Strength (MPa)	Thermal Expansion (10^{-6}/°C))	Thermal Conductivity (W/m-K)
2.7	0.33	70-80	90	48	25	69	55	23.4	218

In the Friction stir process, a localized plastic deformation is used to change the properties of a metal. This plastic deformation is produced by forcing a non-consumable tool into the work piece and the tool is revolved in a stirring motion when it is pushed laterally through the work piece. Friction stir welding is a precursor of this technique, which is used to join multiple pieces of metal without creating the heat affected zone typical of fusion welding [14, 15, 16].

When ideally implemented, this process mixes the material without changing the phase of the material and a microstructure with fine, equiaxed grains is created. This homogeneous grain structure, separated by high-angle boundaries, allows some aluminum alloys to take on super plastic properties [17, 18, 19]. Friction stir processing also enhances the tensile and fatigue strength of the metal [20-23].

The concept of FSP was introduced by [16, 17] to improve the surface strength of magnesium alloy. The result shows that FSP has emerged as an effective tool for enhancing sheet metal properties through microstructure modification. Significant refinement of the grain and the process of homogenization can be achieved in a single FSP pass leading to improved formability, especially at elevated temperatures. Most of the research conducted on FSP has its special advantages than other producing ways. This solid processing focuses on aluminum alloys. Investigation on the effect of various process parameters on thermal histories, resulting microstructure and properties is taking place.

[18, 19, 20] have investigated the mechanical behavior of surface nanocomposite via FSP technique. This paper had given the idea of production of nanocomposite material by the dispersal of nano particles over bulk material. This journal discussed about the fixing of the workpiece material on a rigid back plate in the beginning during the FSP. The friction stir tool penetrates into the plate with high rotational speed, and then head face of shoulder was under the surface at a certain depth. The friction stir tool moved along the fixed track at the end. Hydrogen porosity occurring during the fabrication of aluminium alloys by liquid processing can be reduced by the metal matrix composites (MMCs) using FSP. Dynamic recrystallization in stir zone can also be used to obtain fine grains. Properties of Al2O3 are shown in table 1.3.

Table 1.3 Properties OF Al_2O_3

Density (gm/cc)	Flexural strength (MPa)	Elastic Modulus (GPa)	Poisson's ratio	Shear Modulus (GPa)	Hardness (Kg/mm^2)	Bulk Modulus (GPa)	Thermal Expansion ($10^{-6}/^oC$))	Thermal Conductivity (W/m-K)
3.89	55	375	0.22	152	1440	228	8.4	35

2. Experimental setup

In the Friction stir processing technique, the tool of HSS with speed 1600 rpm, feed rate of 30 mm/min and force of 8 KN is used. As the tool rotates, the stirring and mixing of material around the pin takes place. As the tool rotates at a high speed, it generates a high temperature. This is caused due to the heat produced by friction which leads to the intense stirring and mixing of material. The heating depends upon the frictional coupling of tool surface with work piece. The process is complete when the stirred material is subjected to move from the front to the back of the pin because of the travelling speed of tool. Higher tool traversing speed is associated with the shorter reaction time and lower reaction temperature. Therefore, the distribution of the reinforcement material in the base metal is increased if the travelling speed of the tool is decreased.

Fig:3.1:(a) The design geometry FSP tool

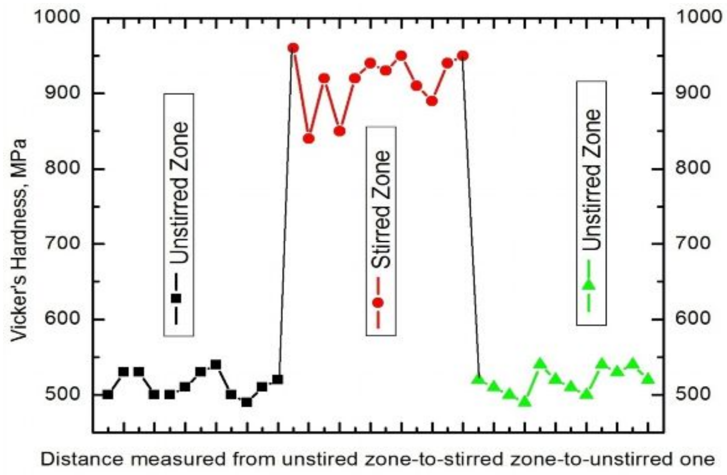
3. Results & Discussion

The table 3.1 shows the comparison of the Vickers microhardness of the surface reinforced AA6063 material and the hardness of unprocessed AA6063 material. We can notice from the comparison that the hardness values of the surface reinforced composite are much higher than the values of the surface which is unprocessed. The values possessed by processed surface seemed to be 1.27 times higher than the values of unprocessed surface. This increase in values was expected to take place due to the refinement of grains which occurs during the FSP process and the strength obtained from the dispersion of Al_2O_3 in the matrix. Results of micro hardness are shown in table 3.1 and graph 3.1

Table 3.1: Results of hardness

Sl.No	**Material / Region**	**Trial-I**	**Trial-II**	**Trial-III**	**Trial-IV**	**Trial-V**	**Average $HV_{0.01}$**
1s	Aluminium AA6063 – unprocessed one	97.6	95.2	95.8	97.4	99.6	97.12
23sx2	Surface reinforced Aluminium AA6063-Al_2O_3 composite processed via FSP	123.2	125.1	120.7	124.5	125.1	123.72

Graph 3.1: Results of hardness



R

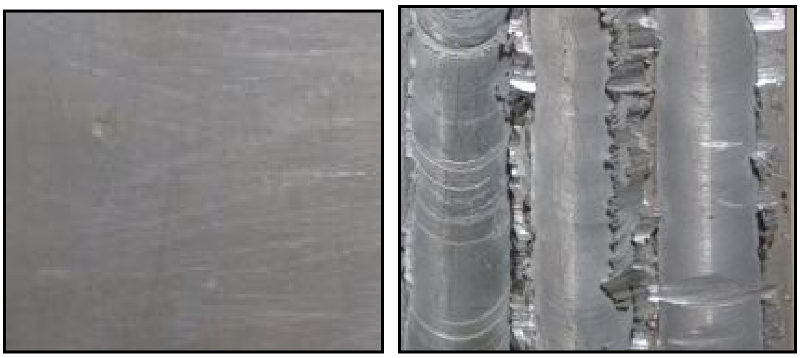


Fig:4.1.: Hardness variation of AA 6063 reinforced with Al_2O_3 surface composite processed by friction stir processing

Microstructure is defined as the small scale structure of a material as revealed by a microscope above 25× magnification. The physical properties such as strength, toughness, ductility, hardness, corrosion resistance, high or low temperature behavior, and wear resistance are heavily influenced by the microstructure of a material. The properties help in the usage of these materials in industries. Microstructure of smaller scales called as the nanostructures are viewed using optical microscopes, where as crystal structures are structures in which individual atoms are arranged and ultrastructure is the nanostructure of biological specimens. We come across the concept of microstructure in macro structural features in our day-to-day life. Galvanized steel, such as the casing of a lamp post or road divider, exhibits a patchwork of interlocking polygons of different shades of grey or silver, which is coloured non-uniformly. Each polygon is a single crystal of zinc which is stuck to the surface of the steel beneath. Large crystals are formed by zinc and lead which are visible to the naked eye. The atoms in each grain are sorted into one of seven 3d stacking arrangements or crystal lattices (hexagonal, orthorhombic, tetrahedral, monoclinic, rhombohedral, triclinic, and cubic) The direction of alignment of the matrices differs between adjacent crystals, leading to variance in the reflectivity of each presented face of the interlocked grains existing on the galvanized surface. The processing conditions and composition controls the average grain size. Most of the alloys have small grains which are not visible to the naked eye. This is to increase the strength of the material (Hall-Petch strengthening). To quantify microstructural features, both morphological and material property must be characterized.

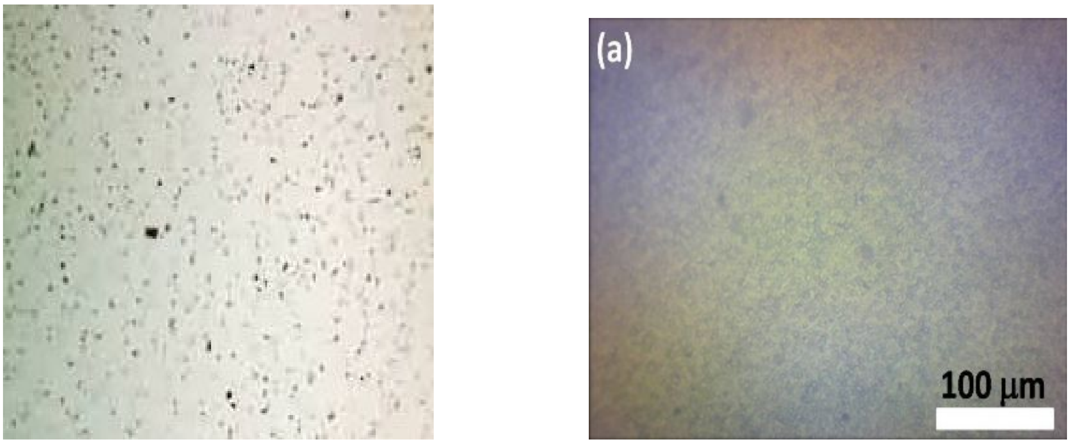


Fig: 4.2: Microstructure of Aluminum plate AA6063 and Microstructure of AA 6063 reinforced with Al_2O_3 composite

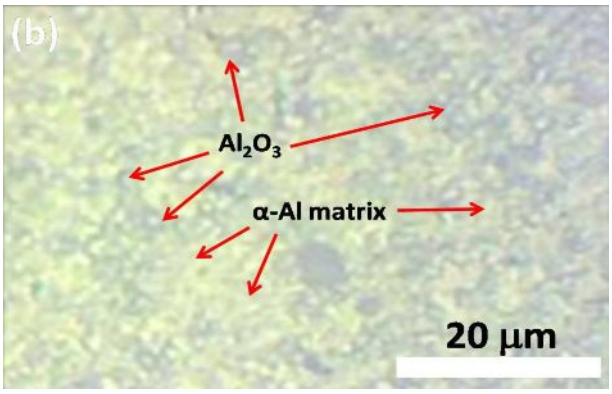


Fig 4.3 Magnified view of the corresponding composite indicates the distribution of Al_2O_3 on the matrix

Fig.4.2 shows the microstructure of Aluminum plate reinforced with Al_2O_3 composite. Further these figures reveal the homogeneity of the composites. It can be observed from the microphotograph that there is an increase in the filler contents of the composites. Fig.4.3 shows the magnified view of Fig.4.2 in which Al_2O_3 is completed dispersed and embedded in the matrix. Thus, It can be concluded that FSP technique is used to fabricate the surface composite easily. Observations made on a survey conducted states that there are more number of successful researches based on surface reinforcement of bulk material which are performed using Friction Stir Processing (FSP) technique. There is a necessity to increase the refinement of grain structure and the surface hardness, in spite of the improvements made on microstructures of the bulk materials by this process. This necessity has lead to further improvement by incorporating nano particles on the surface of bulk materials with the help of FSP.

4. Conclusion

Friction stir processing has immensely high potential in the field of thermo mechanical processing of various alloys mainly the ones made out of aluminium. Preliminary investigation of friction stir processing of alumina particles on the surface of AA6063 is presented in this thesis. This includes presenting of the processing forces and the resultant microstructure for FS processed AA6063. The main motivation behind this project is the optimization of the process, involving the correlation of surface reinforcement and microstructure with the process parameters. It is observed from the results that there was a significant effect of the process parameters like the rotational and translational speeds on the resulting microstructure and the plunge force during FSP of AA6063.

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